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Charlotte, NC BPL Trial System Electromagnetic Emission Tests
Metavox, Inc.
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INTRODUCTION

Metavox, Inc conducted electromagnetic emission testing of the Charlotte, NC BPL trial system. This effort was an independent measurements of the radiated emissions from overhead power line systems distributing Broadband over Power Line (BPL) service to residential subscribers.

BPL systems use digital signal communications of wide bandwidth. The systems are known to occupy spectrum in the frequency region from 1.7 MHz to 30 MHz, with harmonic content into the VHF spectrum. Some of these trial systems operate under Part 5 experimental licenses to conduct testing over a range of 1.7 MHz to 80 MHz.

The purpose of the test conducted here is to measure the field strength of radiated emissions from the BPL system in order to provide a quantitative basis for assessing the potential for interference to licensed radio systems operating in the same frequency range. Most BPL systems seek to operate under limits established by the FCC for Part 15 devices as unlicensed, unintentional emitters. The testing conducted here will assist in efforts to compare the observed BPL emissions to the emission limits established by FCC pertaining to unlicensed devices Specifically, FCC in Part 15 currently "requires that unlicensed devices operating below 30 MHz comply with a quasi-peak radiated emission limit of 30 μV/m at a distance of 30 meters at all frequencies over the range from 1.705 to 30 MHz."

On June 8th, 2004, measurements were taken at a BPL trial system located on Carmel Road at its intersection with Waterford Square Drive. The results of the Metavox tests are tabulated in Appendix 2: Test Data, a description of the testing and test sites is described in the following sections.

APPROACH

Metavox outfitted a mobile van with calibrated emission-measuring equipment (see Appendix 3: Equipment). The mobility is used in the area of a BPL system to first locate specific positions where the BPL radiated emission is clearly detectable. A picture at the Charlotte test site is shown in Figure 1. Figure 2 shows the electronics bench in the van interior with (from left to right on the bottom row of equipment) an HP 141T/8553L/8552A spectrum analyzer, a Tektronix 485 oscilloscope, and the Rohde & Schwarz ESH 2 test receiver. Above them is a Boonton 92A-S2 RF millivoltmeter and a Teac RD-111T PCM instrumentation recorder.

Figure 1 Test Van Set Up at Raleigh NC Test Site

Figure 2 Test Bench Inside Metavox Test Van

For signal level measurements, the ARA BBH-500/B active loop antenna is set out at about 5 to 10 meters from the vehicle as shown in Figure 1. The tripod positions the center of the loop at 160 cm above the ground. The full array of equipment is used in site selection to determine that the BPL signal is distinguishable and that the signal strength is adequately handled within the dynamic range of the instruments. However, in the test measurement process, only the active loop antenna, ARA model Model BBH-500/B and ESH 2 receiver are used for taking data. These instruments are calibrated to standards traceable to National Institute for Standards and Technology (NIST). Each field strength measurement is accurate within ± 1.5 dB since measurement accuracy is the combination of (uncorrelated) factors for the antenna (ARA model Model BBH-500/B) and the test receiver (Rohde & Schwarz ESH2) as given in the Appendix 2: Equipment.

Antenna placement and orientation was made considering all of the conductors of the surrounding power distribution system including the medium voltage power conductors, the secondary cable between transformers and the secondary cables to houses. A measurement of the output of the active loop is first made using a 300 MHz bandwidth Tektronix 485 oscilloscope to insure the active circuits are not overloaded by a strong signal. Measurements were then taken at three orthogonal orientations of the antenna for each frequency. The data presents individual measurements on all three orientations along with the combined 3 axis RMS of the 3 voltages expressed in dB. This value represents the expected maximum if the antenna were orientated for the maximum level. In one case, the vertical orientation was precluded by 60 Hz powerline noise so only 2-axis values are reported. Measurements were made using the receiver's CISPR mode. The CISPR measurement mode provides an objective measure of the effect of an interference on the reception of radio telephony.

Figure 3 Charlotte, NC Test Site Power Pole and Lines Including BPL Installation

TEST DESCRIPTION

Charlotte-1 and Charlotte-2

Testing was performed on a trial BPL system operating at Raleigh NC. (see Appendix 1: Sites, Charlotte-1 and Charlotte-2) on June 8th, 2004. The detailed results are presented in Appendix 2: Test Data, Charlotte-1 for the 30 meter distance and Charlotte-2 for the 51 meter distance. The far right hand column value in each chart represents the worst case interference level if the phases in all three axes were additive. This column contains those single composite values which best illustrate the interference experienced but may not represent non-compliance with FCC Part 15. The single axis measurements should be used to determine compliance. It was reported that this installation was new and had been in place for only several weeks.

Figure 3 shows the overhead line on a pole along Carmel Road at the intersection with Waterford Square Drive. This figure shows three-phase medium voltage lines running along Carmel Road and a three phase medium voltage line plus other lines crossing to Waterford Square Drive. Telephone and fiber optic cables are below the medium voltage lines. A fiber optic junction box on the pole appears to connect to the BPL injection box on the far side of the pole. The BPL injection tap can be seen on the second from the right medium voltage line as it departs from the pole away from the camera position. The BPL interference at this site was impulsive and was distinctive and clearly distinguishable from other users or 60 Hz power line noise.

The antenna was placed at a horizontal range of 30 meters from the medium voltage power conductors. Significant levels of 60 Hz noise were seen at all points in the vicinity of the power lines for hundreds of feet either direction along Carmel Road. It was observed that narrow nulls occurred in the 60 Hz noise every few hundred kilohertz over the observation range. Measurements of the BPL levels were made in these nulls. An additional set of measurements were made at a horizontal distance of 51 meters from the lines. The data sheet reveals that the nulls were at different frequencies from the nulls at the first position.

In addition to 60 Hz power line interference nulls varying with position and frequency, they also varied with antenna orientation. As a result, most frequencies measured would have a null in one orientation while having other 60 Hz interference null frequencies in the other orientations. At the 30 meter distance position no good, deep nulls were observed in the vertical orientation so measurements were only made in two orientations. Few measurements could be made where all three orientations had a null in the 60 Hz noise so few three axis measurements could be made. Valid two or three dimensional BPL measurements are only shown in the 3-axis or 2-axis columns.

Three orthogonal orientations of the antenna were tried: the antenna axis horizontal and parallel to the power lines, horizontal and perpendicular to the power lines, and vertical. Data was taken at frequencies from 6.02 MHz through 18.60 MHz. These frequencies were chosen on site as BPL signal measurement points free of other HF user's signals and 60 Hz power line noise observed in a preliminary scan of the spectrum from 1.7 to 30 MHz.

CONCLUSIONS

Most notable at this site was the strong 60 Hz related interference along with the BPL interference. This site demonstrates that an installer can and does install BPL in the presence of high interference without correcting the 60 Hz noise problem. The existence of nulls in the 60 Hz interference allowed for meaningful measurements of the BPL system. The powerlines clearly radiated BPL interference The 60 Hz interference constrained measuring frequencies so that attempts to measure within the amateur bands were generally not possible. One measurement at 51 meters and 14.35 MHz found the BPL interference but the level was probably within the FCC Part 15 limit since it is below the limit but at 51 versus the 30 meter distance.

The measured interference levels exceeded the FCC Part 15 limits by as much as 3.6 dB at the 30 meter distance.

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Charlotte-1 and Charlotte-2

The Charlotte test site is on Carmel Road at the intersection with Waterford Square Drive. A three- phase overhead medium voltage line runs along the road. This power line is where the BPL test system is installed. The land adjacent to Carmel Road is built up with mixed commercial and residential properties on both sides.

The BPL injection point appears to get its Internet connection from a fiber optic cable connection from a remote site. Testing was conducted on the edge of the parking lot at 6311 Carmel Road.

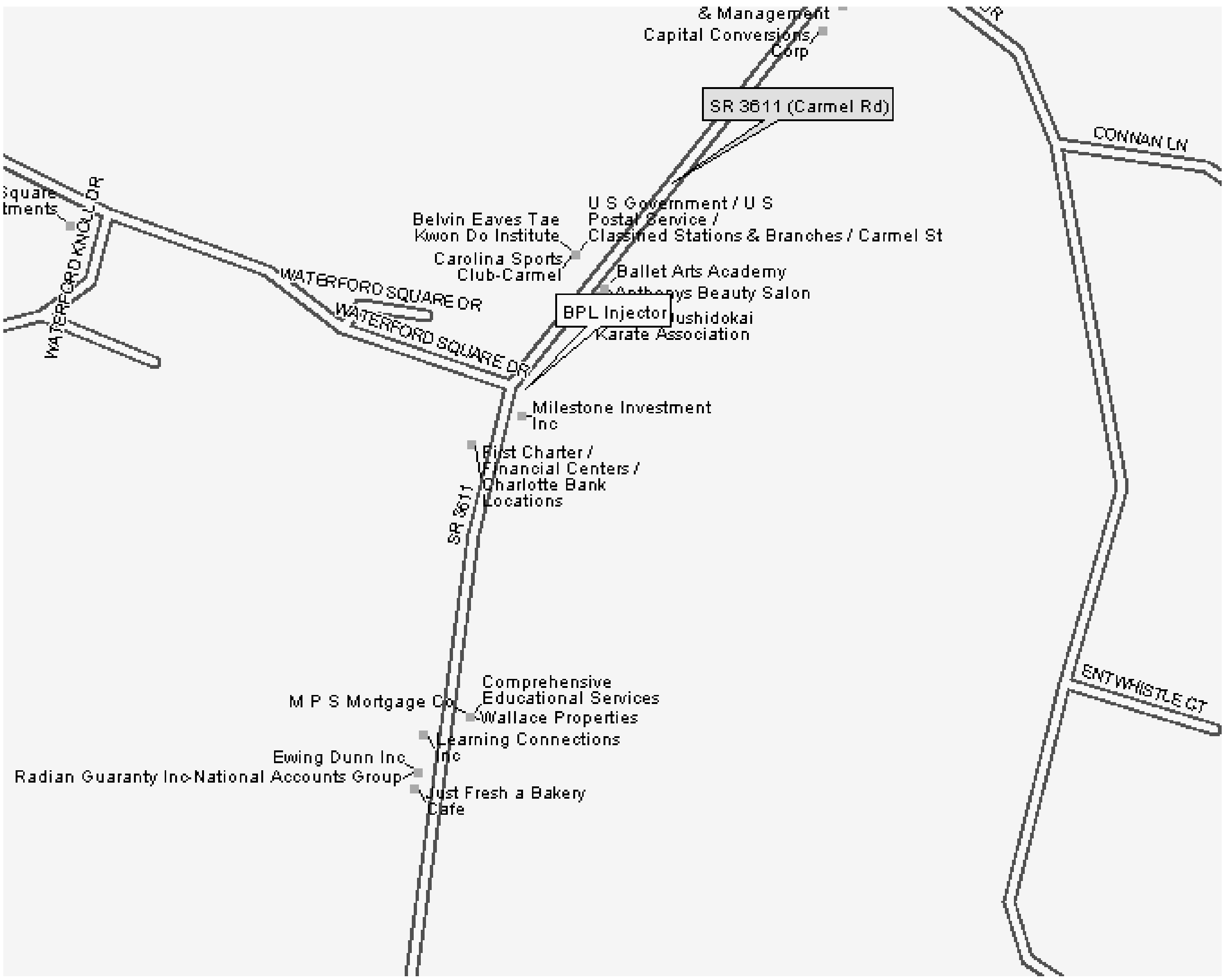

Figure 4 Holland Church Road Injection Node

Site: **Charlotte-1**

Tuesday, June 8, 2004 — 6311 Carmel Rd 30m horizontal, 1.6m above ground adjacent to parking lot

Carmel Rd & Waterford Square Dr

Charlotte NC

H-Probe Antenna: ARA Model BBH-500/B

Freq MHz	‖ Cable ‖ #1 ⇓ dB loss	[‖Antenna Factor (equiv. electrical, interpolated)] ‖ ⇓ dB1/meter	Receiver Indicated Strength // to Line Gain dBμV base	+meter	Receiver Indicated Strength | to Line Gain dBμV base	+meter	Field Strength // to Line dBμV/m	Field Strength | to Line dBμV/m	RMS (2-axis) dBμV/n
6.27	1.30	-6.87	30	8.0 i	30	12.0 Bz	**32.4** i	36.4 Bz	
6.69	1.40	-6.87	20	8.0 i	30	8.0 Bz	**22.5** i	32.5 Bz	
7.00	1.50	-6.87	20	2.0	20	8.0 Bz	16.6	22.6 Bz	
7.30	1.58	-6.87	20	12.0 Bz	30	6.0 Bz	26.7 Bz	30.7 Bz	
7.69	1.70	-6.87	30	3.0 i	30	3.0 Bz	**27.8** i	27.8 Bz	
7.83	1.78	-6.87	30	14.0 i	20	10.0 Bz	**38.9** i	24.9 Bz	
8.01	1.80	-6.87	30	6.0 i	30	3.0 Bz	**30.9** i	27.9 Bz	
9.00	1.60	-6.87	30	5.0 i	30	6.0 Bz	**29.7** i	30.7 Bz	
10.15	1.40	-6.82	30	14.0 Bz	30	13.0 Bz	38.6 Bz	37.6 Bz	
10.55	1.50	-6.69	20	12.0 i	20	12.0 i	**26.8** i	**26.8** i	**29.8**
12.48	1.85	-6.07	30	4.0 i	30	2.0 Bz	**29.8** i	27.8 Bz	
14.00	2.00	-5.57	20	4.0 Bz	30	12.0 Bz	20.4 Bz	38.4 Bz	
14.35	2.00	-5.46	20	6.0 Bz	20	10.0 Bz	22.5 Bz	26.5 Bz	
14.65	2.04	-5.36	30	5.0 i	20	8.0 i	**31.7** i	**24.7** i	**32.5**
15.01	2.05	-5.25	20	4.0 i	20	10.0 Bz	**20.8** i	26.8 Bz	
15.83	2.08	-4.98	20	16.0 i	20	4.0 i	**33.1** i	**21.1** i	**33.4**
17.38	2.15	-4.48	30	4.0 i	20	10.0 i	**31.7** i	**27.7** i	**33.1**
18.60	2.20	-4.19	20	9.0 i	10	12.0 i	**27.0** i	**20.0** i	**27.8**

Site Monitor: antenna output scope (peak-peak)

maximum: 500 mv

Notes:

i:BPL Impulses

Bz: 60Hz power noise

Bold numbers indicate BPL signal field strengths.

FCC limit of 30 uv/meter is 29.5 dB/uv/m

Only 2-axis measurements could be made

Site: **Charlotte-2**

Tuesday, June 8, 2004 6311 Carmel Rd 51m horizontal, 1.6m above surface of parking lot

Carmel Rd & Waterford Square Dr

Charlotte NC

H-Probe Antenna: ARA Model BBH-500/B

Freq MHz	|| Cable || #1 ⇓ dB loss	[||Antenna Factor (equiv. electrical, interpolated)] || ⇓ dB1/meter	Receiver Indicated Strength // to Line Gain dBµV base	+meter	| to Line Gain dBµV base	+meter	Vertical Gain dBµV base	+meter	Field Strength // to Line dBµV/m	| to Line dBµV/m	Vertical dBµV/m	RMS (3-axis) dBµV/m
6.02	1.2	-6.87	20	12.0 i	30	3.0 Bz	10	14.0	**26.3** i	27.3 Bz	***18.3***	
6.65	1.4	-6.87	20	8.0 i	30	5.0 Bz	20	2.0	**26.5** i	29.5 Bz	16.5	
7.17	1.6	-6.87	20	2.0	0	0.0	20	0.0	22.7	-5.3	14.7	
7.66	1.7	-6.87	20	12.0 i	30	12.0 Bz	20	6.0 Bz	**16.8** i	36.8 Bz	20.8 Bz	
7.83	1.7	-6.87	30	6.0 i	20	10.0 i	10	12.0	**30.8** i	**24.8** i	16.8	
8.01	1.8	-6.87	30	2.0 i	20	8.0 i	10	12.0	**26.9** i	**22.9** i	16.9	
8.44	1.7	-6.87	20	8.0 i	20	10.0 Bz	10	10.0	**22.8** i	24.8 Bz	14.8	
8.70	1.7	-6.87	20	2.0 i	30	8.0 Bz	20	4.0 Bz	**16.8** i	32.8 Bz	18.8 Bz	
9.22	1.6	-6.87	20	4.0 i	30	2.0 Bz	20	2.0	**18.7** i	26.7 Bz	16.7	
10.15	1.4	-6.87	20	8.0 Bz	30	8.0 Bz	20	6.0 Bz	22.6 Bz	32.6 Bz	20.6 Bz	
12.10	1.8	-6.19	20	10.0 i	20	4.0 i	10	10.0 i	**25.6** i	**19.6** i	**15.6** i	**26.9**
13.16	1.9	-5.85	20	4.0 i	20	5.0 Bz	10	6.0	**20.1** i	21.1 Bz	12.1	
14.00	2.0	-5.57	20	2.0 Bz	30	4.0 Bz	20	6.0 Bz	18.4 Bz	30.4 Bz	22.4 Bz	
14.35	2.0	-5.46	20	2.0 Bz	20	5.0 Bz	10	10.0 i	18.5 Bz	21.5 Bz	**16.5** i	
14.65	2.0	-5.36	20	12.0 i	10	16.0 i	10	10.0 i	**28.7** i	**22.7** i	**16.7** i	**29.8**
15.01	2.0	-5.25	20	6.0 i	20	2.0 i	10	10.0 i	**22.8** i	**18.8** i	**16.8** i	**25.0**
15.78	2.1	-5.00	20	2.0 i	20	2.0 Bz	10	4.0	**19.1** i	19.1 Bz	11.1	
16.20	2.1	-4.90	20	6.0 i	20	4.0 i	20	2.0 i	**23.2** i	**21.2** i	**19.2** i	**26.3**

Site Monitor: antenna output
scope (peak-peak)
maximum: 500mv

Notes:
i:BPL Impulses
Bz: 60hz power noise
Bold numbers indicate BPL signal field strengths.

Appendix 3: Equipment

Metavox tests used equipment calibrated to standards traceable to National Institute for Standards and Technology (NIST):

- Amplified magnetic-field antenna
- Receiver capable of tuning the HF band, with quasi-peak detection matching CISPR specifications.

Amplified H-Field Antenna: ARA Technologies, Inc., Model BBH-500/B, Serial Number 311

Reference: "Data Book, Magnetic Field Antennas, BBH-500/B", page 42; Antenna Research Associates, Inc, Beltsville, Maryland, 20705

The BBH series of broadband magnetic field (H field) receiving antennas are designed to provide maximum sensitivity for receiving magnetic field signals in the VLF, 100 Hz, through VHF, 100MHz, spectrum. These antennas are responsive primarily to the magnetic component of an electromagnetic field with practically no sensitivity to the electric component. The electrical balance with respect to ground and cable renders them almost immune to common mode interference. They exhibit remarkably clean reception in environments of locally generated man-made noise.

The far-field receiving pattern is that of an elementary dipole with nulls of approximately –20 dB occurring off the ends of the rod. Integral active networks ensure the highest possible sensitivity. The BBH antennas yield much greater accuracy in measuring the tangential field of a source at close range than is possible with typical air core loops.

An internal power supply and rechargeable batteries in these antennas minimize disturbances and permit operation under practically any condition.

Magnetic field strength indication from the H-field antenna device is converted to electric field strength by the free space impedance with the common value of 377Ω:

$$af^{electric}{}_{(dB/m)} = af^{magnetic}{}_{(dB/m)} + 51.35_{dB\Omega}$$

The noise floor of the H-field antenna using the manufacturer's specifications, and scaled to the CISPR bandwidth of 9kHz, (i.e. 9.54 dB relative to 1kHz) is:

Frequency, MHz:	1	3	10	30
Noise Floor Field Strength, $dB_{\mu V/m}$:	34.9	5.9	2.9	10.9

Calibration: The Antenna Research Associates Model BBH-500/B, Serial Number 311, was calibrated by Liberty Laboratories Inc., 1346 Yellowwood Road, Kimberton, IA 51543, on Thursday, February 19, 2004, with Certification number: 2004021814 issued to Metavox, Inc.

Traceability: Certificates of Liberty Laboratories state that:

All measurement instrumentation is traceable to the National Institute of Standards and Technology (NIST). Supporting documentation relative to traceability is on file and is available for examination upon request. Measurement procedures per Military Handbook 52A as guidance for Military Standard (MIL-STD) 45662A, ANSI/NCSL Z540-1-1994, ISO/IEC 17025 and Liberty Labs,Inc. procedure OP-2.

<u>Accuracy</u>: The electrical equivalent antenna factor $af^{electric}_{BBH\ (dB/m)}$ is accurate within 0.9 dB for the frequency range from 1 to 30 MHz and certified by the calibration.

<u>Receiver:</u> Rohde and Schwarz Model ESH2, Serial Number 831436/006

Reference: "Data Sheet, Test Receiver ESH 2", Rohde & Schwarz, Republic of Germany.

The Test Receiver ESH 2 is a manually operated, highly sensitive and overload-protected test receiver offering a very wide dynamic range. Compact design, the wide range of power supplies that can be used, and low power consumption make the receiver suitable for use in fixed stations as well as for mobile and portable applications, such as field-strength measurements.

The ESH 2 can tune from 9kHz to 30MHz and operates as a selective voltmeter in a level range from –30 to +137 $dB_{\mu V}$ *in 50 Ω systems. Overload of the input or of other important circuits is detected and signaled by the test receiver.*

Selection of "CISPR quasi-peak weighted" detection provides an IF bandwidth (-6 dB) for measurements according to CISPR Publications 1 and 3 with 9kHz bandwidth for the HF frequency range.

<u>Calibration</u>: The Rohde & Schwarz Model ESH2, Serial Number 831436/006, was calibrated by Industrial Process Measurement, Inc, Edison, NJ,08820, on February, 5, 2004, with Certificate number 23725-01.

<u>Accuracy</u>: The frequency accuracy in the range of 1-30 MHz is +/- 0.00050 MHz.

The frequency response over the 0.01-30 MHz range, at a signal level of 80.0 $dB_{\mu V,}$ is accurate to +/- 1 $dB_{\mu V}$ and certified by the calibration.